Investigation into DFIG Based DC Topologies : A Review on Features

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***Abstract*— The Doubly Fed Induction Machine is widely used in adjustable-speed drives because of the decreased value of power electronics involved in it, the frequency and amplitude of speed is at a stable value even when wind if fluctuating, the speed can be varying around 35% around synchronous speed.. The power electronic components are used for controlling the currents in rotor to get the variable speed imperative to extract maximum energy in variable winds. Because of its wide advantages, it is used in vastly in wind power generation. Apart from this use where a back-to-back converter is used to control DFIG, which is mostly the VSC back to back converter, nowadays there has been a growth in unconventional DFIG drives for generating DC power. More and more research is being done in this field using power electronics. It combines DFIG high freedom for control with easy power electronic interfaces to get a less expensive and fully-controlled system. Though many concepts have been presented in research work, there is dearth of differentiation among different topologies. Hence this gives a review of recent topologies.**

Keywords- DFIG, power converter.

1. INTRODUCTION

Doubly fed induction machine (DFIM) or wound rotor induction machine (WRIM) is based on the principle of electromagnetic induction just like an induction machine, the only difference being that here both stator and rotor are supplied with three phase AC voltage [1]. The stator is excited with 3φ voltages from the grid directly at constant amplitude and frequency, which creates the magnetic field of stator. The constant amplitude of the rotating magnetic flux is $3/2\emptyset_m$. The rotor is also excited by 3 φ voltages which take a different amplitude and frequency to reach different operating conditions of the machine. This is implemented by using a VSC, as represented in the figure1. This converter along with the proper control strategy is in charge of controlling the required rotor AC voltages to control the DFIM.The rotor frequency is different from the stator. It is slip*frequency. Slip value is between 0 and 1 and is usually 4%. So, 4% of 50Hz is 2 Hz.

The below figure shows the single-phase equivalent circuit of DFIG. The stator and rotor are showcased with only one phase [2]. The variables mentioned in the diagram are as follows:

V_s : Supplied stator voltage
V_r' : Supplies rotor voltage
I_s : Stator current
$I_r{}'$: Rotor current
E_s : EMF induced in stator
E_{rs}' : EMF induced in rotor
R_s : Stator resistance (Ω)
R_r' : Rotor resistance (Ω)
L_m : Mutual Inductance (H)
$L_{\sigma s}$: Stator leakage inductance (H)
$L_{\sigma r}'$: Rotor leakage inductance (H)

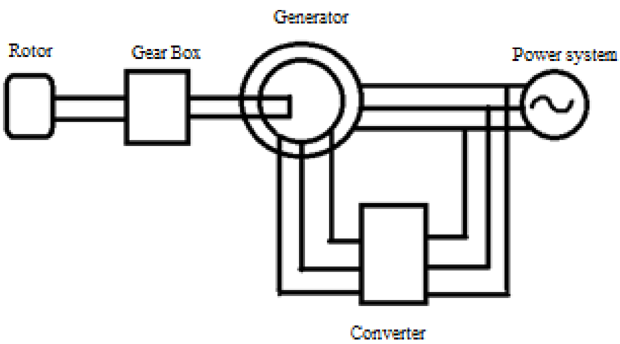

Fig. 1: Principle of a DFIG connected to a wind turbine.

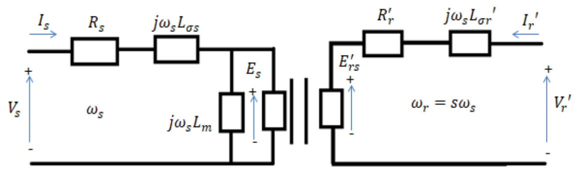

Fig. 2: The single phase steady state equivalent circuit of DFIG.

The steady state equations for DFIG equivalent circuit are as follows:

$\omega_s = \omega_r + \omega_m$ (1)

$\omega_m = p\Omega_m$ (2)

$s = (\omega_s - \omega_m)/\omega_s = \frac{\omega_r}{\omega_s}$ (3)

In the above equations;

$\omega_s - Voltage\ and\ current\ frequency\ of\ stator$

$\omega_r - Voltage\ and\ current\ frequency\ of\ rotor$

$\omega_m - electrical\ speed\ of\ rotor$

$p - pole\ pairs\ of\ the\ machine$

$\Omega_m - mechanical\ shaft\ speed$

$s - slip\ of\ the\ machine\ in \frac{rad}{s}$

Research is being done on different DFIG system topologies for applications like variable-frequency adjustable speed generation, dual converter topologies [3]. DFIG is flexible and controllable. So they use these advantages to decrease ratings, sizes and no. of power electronics. The main use nowadays is in DFIG based DC systems used primarily in wind power generation, distributed generation and dc microgrids. DFIG is capability of operating with adjustable-speed and fixed frequency [4]-[5]. It avoids the intrinsic oversizing penalty like slip ring synchronous generator plus uncontrolled rectifier will experience when operating at variable speed and constant voltage. These ideas are still being researched and there is dearth of comparison between different topologies. This paper aims to review DFIG based dc power generation drive topologies.

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2. Types of DC Topologies

The different layouts representing dc topologies of DFIG are as follows:

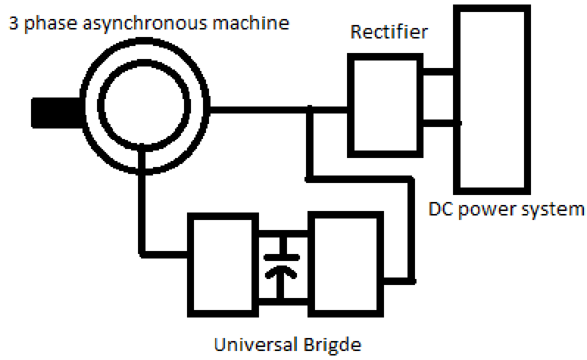

Fig: 3a: Topology-1.

This is made from basic concept with VSC, by introducing a bridge of diodes at the common point of the stator and grid-side VSI converter. The rotor-side converter regulates the stator frequency and torque [6]. The VSI converter on the grid side behaves as filter to compensate for harmonics and have sinusoidal waveforms and ripple-free torque at the DFIG. It is very flexible[7]. It requires two VSI converters and, one bridge, and also reactors . This causes increase in costs.

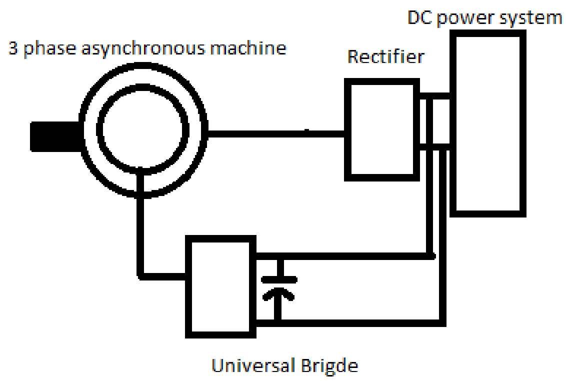

Fig : 3b: Topology-2.

This the first topology was made better in the next topology by removing the common point VSI and connecting bridge(made of diodes) and rotor-side VSI on the same dc-link .This topology is also called as DFIG based dc system. It offers the edge of using only a cheap diode bridge and a low-rated VSI [8]. The disadvantages are distorted currents and voltages caused by the diode-bridge .There are strategies to lessen their effect on the torque. As an alternate diode bridge can be connected to the rotor and the VSI to the stator terminals[9]. A single-VSI layout was also suggested where the stator feeds only stand-alone ac loads .The rotor side (unique) VSI dc-link is connected to a dc-microgrid. Disadvantage of this topology is the dc power flow is not controllable because it depends on the rotor slip[3].

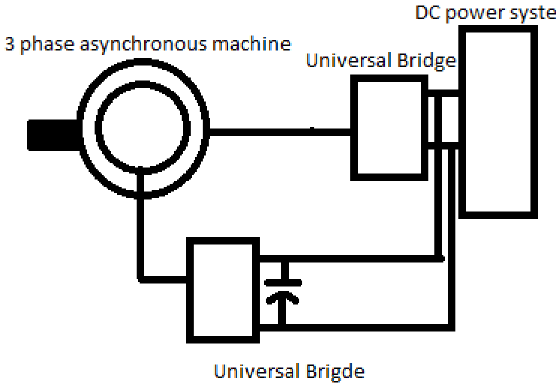

Fig: 3c: Topology-3.

A further change was made by removing the diode bridge and moving to the double-VSI structure .Both the VSI are connected in parallel with the dc power system[11]-[12]-[13] .

The below scheme ensures that its connection to a dc power system is allowed with maintenance of ac load supply. Hence it is known as the hybrid ac-dc solution [14]. A twelve pulse diode bridge is used for the ac load power quality requirements [15]. The common problem of LVRT is taken into consideration which may occur due to the direct ac connection.

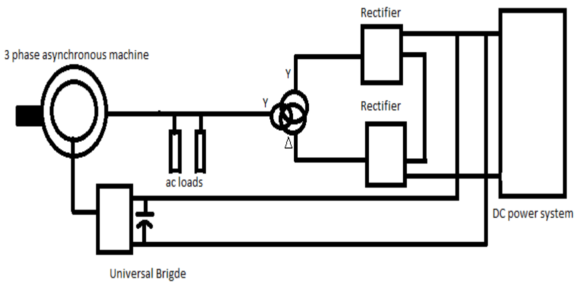

Fig. 3d: Topology-4.

In the below block diagram the three phase ac supply to the stator is being connected to a rectifier which converts ac to dc the capacitor is connected and finally the dc grid is connected.

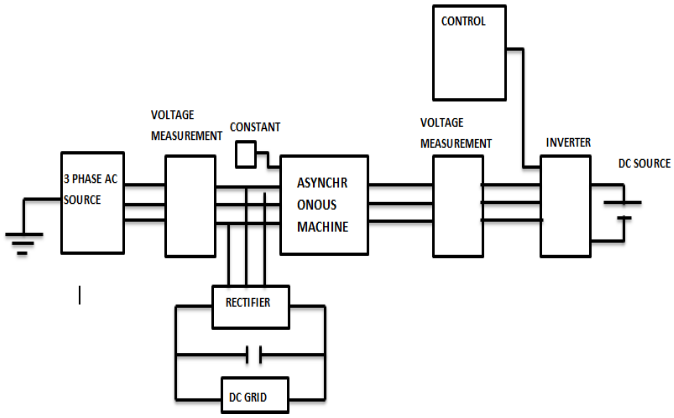

Fig. 4 – Block diagram of the implementation of dc grid at the rotor side .

3. CONCLUSION

The four different dc topologies of DFIG well suited for dc grid have been summarized. The first topology includes a rectifier at the junction point of both grid and stator. The second topology differs from the first in a way that the rectifier is removed from its previous position and connected with the rotor on the same dc link. In the third topology the rectifier is replaced with the universal bridge with IGBT and diodes. In the fourth topology the common problem of LVRT is taken into consideration which may occur due to the direct ac connection. The power quality is enhanced by double VSI topology but the expense is increased by the VSI and controlled converter addition to the circuit. The reviewed topologies have greater degree of freedom and high complexity with expensiveness. The proposes dc topology has less degree of freedom making it much more simpler and cost effective as only rectifier and a small capacitor is incorporated. There are several areas in which further research can be carried out on these topologies.

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